



Chapter 8: Boat Characteristics



Overview

Introduction

Knowledge of your boat's characteristics is crucial in performing safe boat operations. All crew members must be able to recognize and correctly apply boat related terminology. They must also be able to locate any piece of gear quickly and to operate all equipment efficiently, even in the dark. To accomplish these tasks, crew members must be familiar with the boat's layout. Each boat has specific operational characteristics and limitations. These are outlined in the boat's standard manuals or for non-standard boats, in the owner/operator manual. Some types of characteristics that the boat crew should be familiar with include:

- maximum speed
- economical cruising speed
- maximum range at various speeds
- maximum endurance of boat at cruising speed
- minimum required crew size
- maximum number of people that can be safely carried
- maximum load capacity

This section covers the basic knowledge needed to know your boat. For additional definitions, see the Glossary.

In this chapter

These items are discussed in this chapter:

Section	Title	See Page
A	Boat Nomenclature and Terminology	8-3
B	Boat Construction	8-7
C	Watertight Integrity	8-27
D	General Boat Equipment	8-31
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Coast Guard Boat Crew Seamanship Manual



Section A. Boat Nomenclature and Terminology

A.1. General

As with any profession or skill, there are special terms that mariners use. Many of these terms have a fascinating history. Fellow mariners will expect that you are familiar with these terms and use them in your routine conversation. Many of these words will be discussed within this section.

A.2. Definitions

The following are common terms used for location, position and direction aboard a boat. Figure 8-1 provides a diagram of a boat with the more common terms noted.

A.2.a. Bow

The front end of a boat is the bow. When you move toward the bow, you are going **forward**; when the boat moves forward, it is going **ahead**. When facing the bow, the front right side is the **starboard bow**, and the front left side is the **port bow**.

A.2.b. Amidships

The central or middle area of a boat is amidships. The right center side is the **starboard beam**, and the left center side is the **port beam**.

A.2.c. Stern

The rear of a boat is the stern. When you move toward the stern, you are going **aft**. When the boat moves backwards, it is going **astern**. If you are standing at the stern looking forward, you call the right rear section the **starboard quarter** and the left rear section the **port quarter**.

A.2.d. Starboard

The entire right side of a boat, from bow to stern.

A.2.e. Port

The entire left side of a boat, from bow to stern.

A.2.f. Fore and aft

A line, or anything else, running parallel to the centerline of a boat.

A.2.g. Athwartships

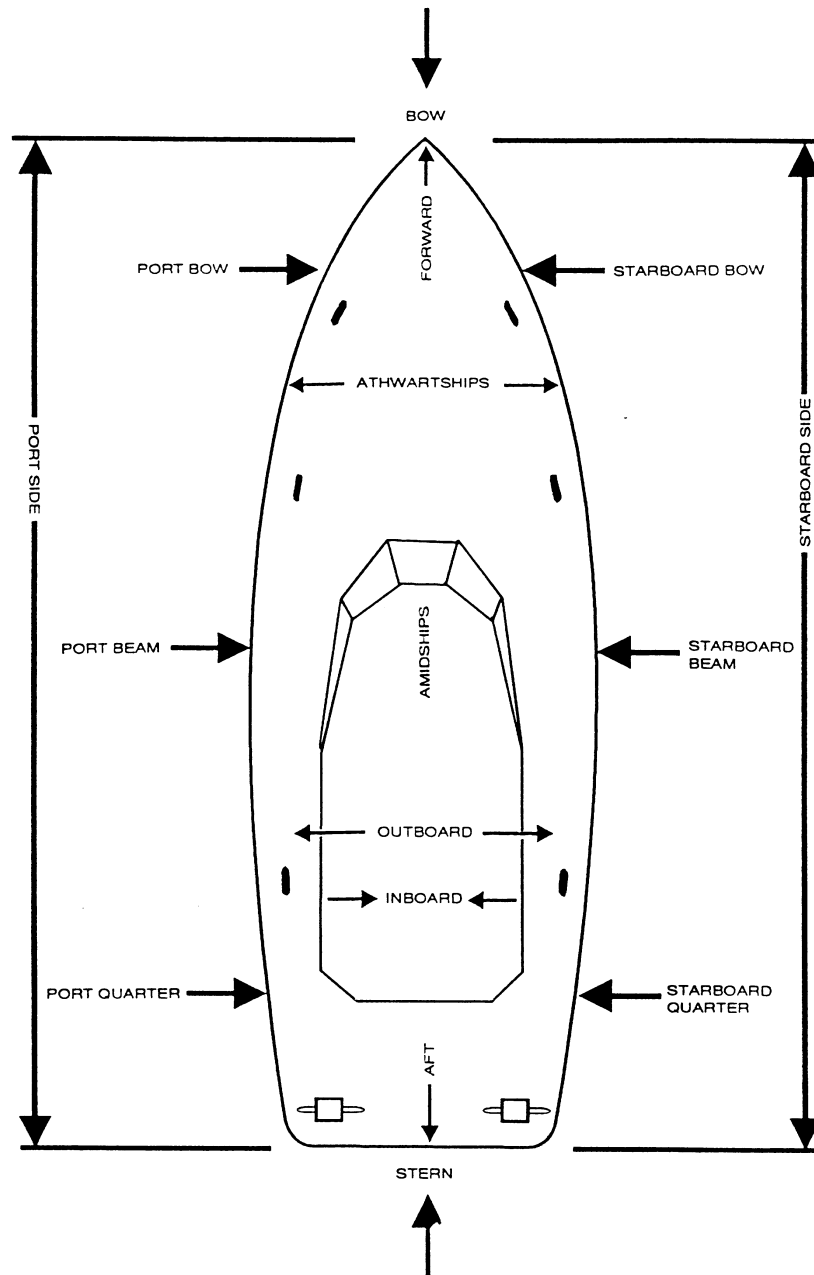
A line or anything else running from side to side.

A.2.h. Outboard

From the centerline of the boat toward either port or starboard side.



A.2.i. Inboard	From either side toward the centerline. However, there is a variation in the use of outboard and inboard when a boat is tied up alongside something (e.g., pier or another vessel). The side tied up is inboard; the side away is outboard.
A.2.j. Going topside	Moving from a lower deck to a weather deck or upper deck.
A.2.k. Going below	Moving from an upper deck to a lower deck.
A.2.l. Going aloft	Going up into the boat's rigging.
A.2.m. Weather deck	Deck exposed to the elements (weather).
A.2.n. Lifelines	Lifelines or railings, erected around the edge of weather decks, are all technically called lifelines although they may have different proper names.
A.2.o. Windward	In the direction from which the wind is blowing; toward the wind.
A.2.p. Leeward	Opposite point from which the wind is blowing; away from the wind. Pronounced "loo-urd".



Position and Direction Aboard Boats
Figure 8-1



Chapter 8: Boat Characteristics



Section B. Boat Construction

Overview

Introduction

Boat construction covers terms that the boat crew will use on a daily basis in normal conversations and in operational situations. Proper understanding of these terms and concepts has importance that an inexperienced sailor may overlook.

In this section

These items are discussed in this section:

Topic	See Page
Hull Types	8-8
Keel	8-14
Principle Boat Parts	8-15
Hatches and Doors	8-22
Boat Measurements	8-24
Displacement	8-25



Hull Types

B.1. General

The hull is the main body of a boat. It consists of a structural framework and a skin or shell plating. The hull may be constructed of many different materials, the most common being metal or fiberglass. A metal skin is usually welded to the structural framework, although riveting is sometimes used. A vessel could be monohull or multi-hull, such as catamarans and trimarans. The three basic types of hull forms based on vessel speed are:

- Displacement hull
- Planing hull
- Semi-displacement hull

B.2. Factors influencing hull shapes

Many factors influence hull shapes and affect the boat's **buoyancy** (its ability to float) and **stability** (its ability to remain upright). Factors that influence hull shapes are discussed as follows:

Factor	Description
Flare	Flare is the outward turn of the hull as the sides of the hull come up from the water line. As the boat is launched into the water, the flare increases the boat's displacement and creates a positive buoyant force to float the boat.
Tumble home	Tumble home is the reverse of flare and is the shape of the hull as it moves out going from the gunwale to the water line. This feature is most noticeable when viewing the transom of an older classic cruiser.
Camber	A deck usually curves athwartships, making it higher at the centerline than at the gunwales so the water flows off the deck. This curvature is called camber .
Sheer	Sheer is the curvature of the main deck from the stem to the stern. When the sheer is pronounced and the bow of the boat is higher than the main deck at amidship, additional buoyancy is provided in the bow. Reserve buoyancy is the additional flotation provided by flare and sheer.



Chine	The turn of the boat's hull below the water line is called the chine . It is "soft" if it is rounded and "hard" if it is squared off. Chine affects the boat's speed on turning characteristics.
Transom	The transom at the stern of the boat is either wide, flat, or curved. The shape of the stern affects the speed, hull resistance, and performance of the boat.
Length on Water Line Length	The boat's length on water line (LWL) is the distance from the bow to the stern, measured at the water line when the boat is stationary. Note that this length changes as the boat rides high or low in the water. Another way of measuring the length of the boat is the length of the craft from its stem to its stern in a straight line. This is termed length over all (LOA) and does not change according to the way the boat sits in the water.
Beam and Breadth	Beam and breadth are measures of a boat's width. Beam is the measurement of the widest part of the hull. Breadth is the measurement of a frame from its port inside edge to its starboard inside edge. a) Molded beam is the distance between outside surfaces of the shell plating of the hull at its widest point. b) Extreme breadth is the distance between outside edges of the frames at the widest point of the hull.
Draft	Draft is the depth of the boat from the actual waterline to the bottom of its keel.
Draft, Appendage	Draft appendage is the depth of the boat from the actual water line to the bottom of its keel or other permanent projection (e.g., propeller, rudder, skeg, etc.), if such a projection is deeper than the keel. The draft is also the depth of water necessary to float the boat. The draft varies according to how the boat lies in the water.
Trim	Trim is a relative term that refers to the way the boat sets in the water and describes generally its stability and buoyancy. A change in trim may be defined as the change in the difference between drafts forward and aft. A boat is trimmed by the bow when the draft forward increases and the draft is greater than the stern draft. A boat is trimmed by the stern if it is down by the stern.



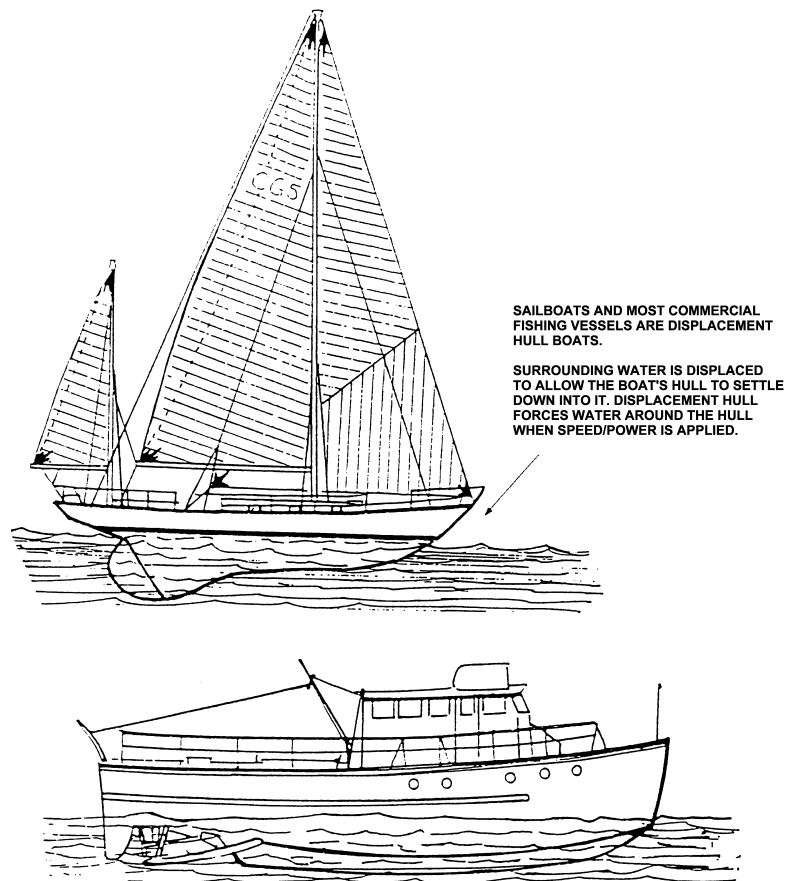
B.3. Displacement hull

A displacement hull boat pushes away (displaces) water allowing the hull to settle down into the water. Underway, the hull pushes out this water, creating waves. (See Figure 8-2) The water separates at the bow and closes at the stern. Tremendous forces work against a displacement hull as the power pushing it and the boat's speed both increase. At maximum displacement speed, there is a distinct **bow** and **stern** wave. The length of these waves depends upon the boat's length and speed. (The longer the boat the longer the wave length.) The bow and the stern ride lower in the water as you increase speed and the water level alongside, amidships becomes lower than that of the surrounding water.

This is caused by the increase in the velocity of the water flowing under the boat and its interaction with the bow and stern wave. As the boat travels along, it rides in a depression created by its own passage. The displacement hull vessel's maximum speed is determined by the vessel's waterline length. Heavy displacement hulls cannot exceed a speed of 1.34 times the square root of their waterline length without requiring excessive power. This speed is known as **critical** speed. When towing a vessel, you must be careful not to tow beyond that vessel's critical speed. For details on towing displacement hulls, see *Chapter 17, Towing*.

WARNING

When towing a vessel, be careful not to tow beyond the vessel's design speed.



Displacement Hulls
Figure 8-2

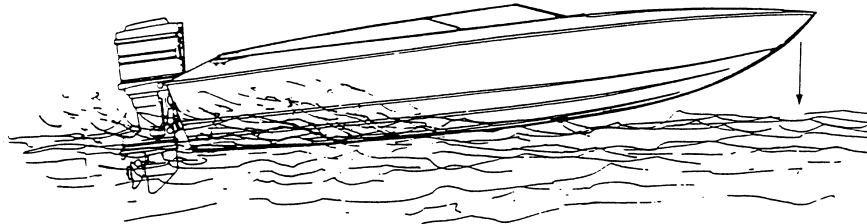
B.4. Planing hull

At rest the planing hull and the displacement hull both displace the water around them. The planing hull reacts nearly the same as a displacement hull when it initially gets underway - it takes considerable power to produce a small increase in speed. But at a certain point, external forces acting on the shape cause an interesting effect - the hull is lifted up onto the surface of the water. (See Figure 8-3) The planing hull skims along the surface of the water whereas the displacement hull always forces water around it. This is called planing. Once "on top," the power/speed ratio is considerably altered--very little power increase results in a large increase in speed. You must apply power gradually when going from the displacement mode to the planing mode or from the planing mode to the displacement mode. When you decrease the power gradually, the hull makes an even,

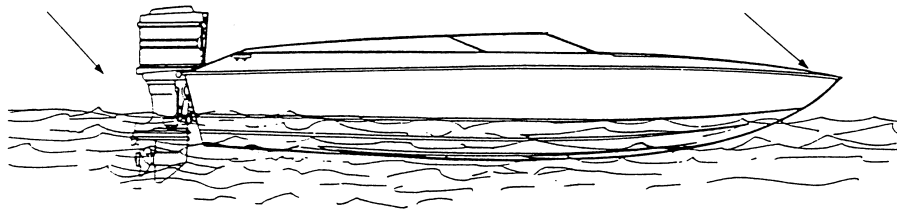


steady transition, like slowly moving your hand from above the water's surface, through it, and into the liquid below. However, if power is rapidly decreased the transition will be a rough one, for the hull will slap the surface of the water like the slap resulting by hitting a liquid surface with your hand.

WHEN SPEED/POWER IS APPLIED, THE PLANING HULL SKIMS ALONG THE SURFACE OF THE WATER.



AT REST, THE PLANING HULL AND DISPLACEMENT HULLS ARE BASICALLY THE SAME, OTHER THAN SHAPE.



Planing Hulls
Figure 8-3

Additionally, the rapid "re-entry" into the displacement mode from above the surface, through the surface, and back into the water causes rapid deceleration as the forces in the water exert pressure against the hull. The effect is like rapidly braking an automobile.



B.5. Semi-displacement hull

The semi-displacement hull is a combination of characteristics of the displacement hull and the planing hull. Many Coast Guard boats are this type (e.g., 44 ft MLB). This means that up to a certain power level and speed (power/speed ratio), the hull remains in the displacement mode. Beyond this point, the hull is raised to a partial plane. Essentially, the semi-displacement hull, like the displacement hull, always remains in the water; it never gets "on top." When in the displacement mode, the power/speed ratio is similar to the power/speed ratio described above for the displacement hull. When in the semi-planing mode, it is affected by a combination of forces for the displacement mode and some for the planing mode. Thus, while a small power increase will increase speed, the amount of resulting speed will not be as great as the same power increase would produce for a planing hull.



Keel

B.6. General

The keel is literally the backbone of the boat. It runs fore and aft along the center bottom of the boat.

B.7. Keel parts

The following are all integral parts of the keel.

B.7.a. Frames

Frames are attached to the keel which extend athwartships (from side to side). The skin of the boat is attached to the frames. The keel and the frames strengthen the hull to resist external forces and distribute the boat's weight.

B.7.b. Stem

The **stem** is an extension of the forward end of the keel. Although there are a number of common stem shapes, all are normally slanted forward (raked) at an upward angle to reduce water friction.

B.7.c. Sternpost

The **sternpost** is a vertical extension of the aft end of the keel.

B.8. Keel types

There are many types of keels. However, in metal boats, there are two types of particular interest: the bar keel and the flat plate keel.

B.8.a. Bar keel

The bar keel is popular because its **stiffeners** (vertical or upright members which increases strength) protects the boat's hull plating if the boat grounds on a hard bottom. It also reduces rolling in much the same way as the more modern bilge keel does. The bilge keel is a fin or stabilizer fastened horizontally to the turn of the bilge. A disadvantage of the bar keel is that, because it extends below the bottom of the boat, it increases the boat's draft.

B.8.b. Flat or flat plate keel

It consists of an "I" beam fastened to the flat plate or it may be built-up from a "rider plate" - a metal plate reinforcing the upper or inner surface of the keel, a vertical keel, and a flat keel. The flat keel, with its vertical keel and rider plate, is built within the boat's hull.



Principle Boat Parts

B.9. Bow

The shape of a boat's bow, its profile, form, and construction determine hull resistance as the boat advances through the water. Hull resistance develops from friction and from the wave the hull makes as it moves in the water. Wave making resistance depends on the boat's speed.

The bow of a boat must be designed with enough buoyancy so it lifts with the waves and does not cut through them. The bow flare provides this buoyancy.

Boats intended for operation in rough seas and heavy weather have "full" bows. The bow increases the buoyancy of the forward part of a boat and deflects water and spray. When a boat is heading into a wave, the bow will initially start to cut into the wave. It may be immersed momentarily if the seas are rough. As the bow flare cuts into the wave it causes the water to fall away from a boat's stern, shifting the center of buoyancy to move forward from the center of gravity. The bow lifts with the wave and the wave passes under the boat, shifting the center of buoyancy aft. This action causes the bow to drop back down and the vessel achieves a level attitude.

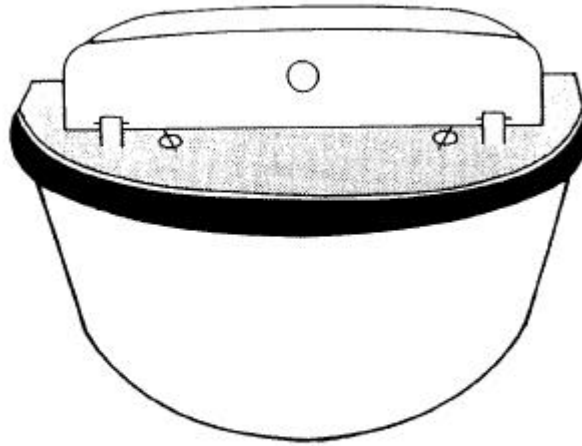
B.10. Stern

The shape of the stern affects the speed, resistance, and performance of the boat. It also affects the way water is forced to the propellers.

The design of the stern is critical in following seas where the stern is the first part of a boat to meet the waves. If the following waves lift the stern too high, the bow may be buried in the sea. The force of the wave will push the stern causing it to pivot around toward the bow. If this is not controlled, the result can be that a boat pitch poles or broaches.

B.10.a. Rounded type stern

The rounded, cruiser type stern presents less flat surface area for a following sea to push upon (See Figure 8-4).

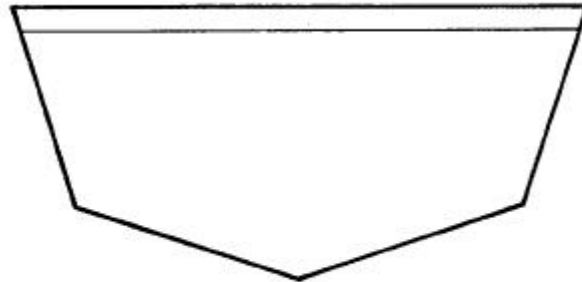


THE ROUNDED CRUISER STERN PRESENTS
LESS FLAT SURFACE AREA FOR THE SEA
TO ACT UPON.

Rounded Cruiser Type Stern
Figure 8-4

**B.10.b. Cruiser type
stern**

The cruiser type stern tends to split the waves of a following sea allowing it to pass forward along each side of the boat. Thus the wave has minimum impact on the attitude of the vessel and provides additional buoyancy for the stern. Always steer into any sideways movement of the stern. For example, when the stern slips to starboard, turn to starboard. It is particularly important that these corrections be made quickly and accurately in short, choppy following seas. Transom sterns provide a larger surface area for the seas to push upon and should not be exposed to heavy following seas or surf conditions (See Figure 8-5).



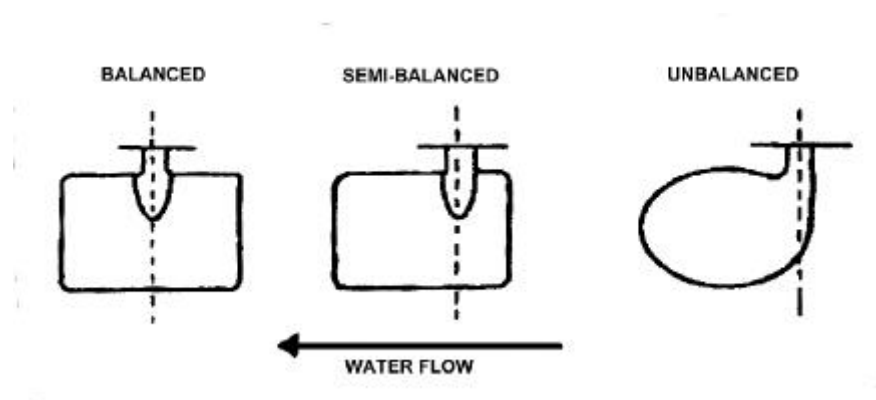
TRANSOM STERNS PROVIDE A LARGE SURFACE AREA FOR THE SEA TO ACT UPON, AND SHOULD NOT BE EXPOSED TO HEAVY FOLLOWING SEAS OR SURF CONDITIONS.

Transom Stern
Figure 8-5

B.11. Rudder

The rudder controls the direction of the boat and may vary widely in size, design, and method of construction. The shape of the stern, the number of propellers, and the characteristics of the boat determine the type of rudder a boat has. Rudder types are shown in Figure 8-6:

- Balanced - blade about half forward and half aft of the rudder post
- Semi-balanced - more than half of the blade aft of the rudder post
- Unbalanced - blade entirely aft of the rudder post



Rudder Types
Figure 8-6



B.12. Propeller

Most boats are driven by one or more screw propellers which move in spirals somewhat like the threads on a screw. That is why the propeller is commonly referred to as a screw. The most common propellers are built with three and four blades. The propeller on a single-screw boat typically turns in a clockwise direction (looking from aft forward) as the boat moves forward. Such screws are referred to as "right-handed." On twin screw boats, the screws turn in opposite directions, rotating outward from the centerline of the boat. The port screw is "left-handed" and turns counter-clockwise. The starboard screw is "right-handed" and turns clockwise.

B.12.a. Propeller parts

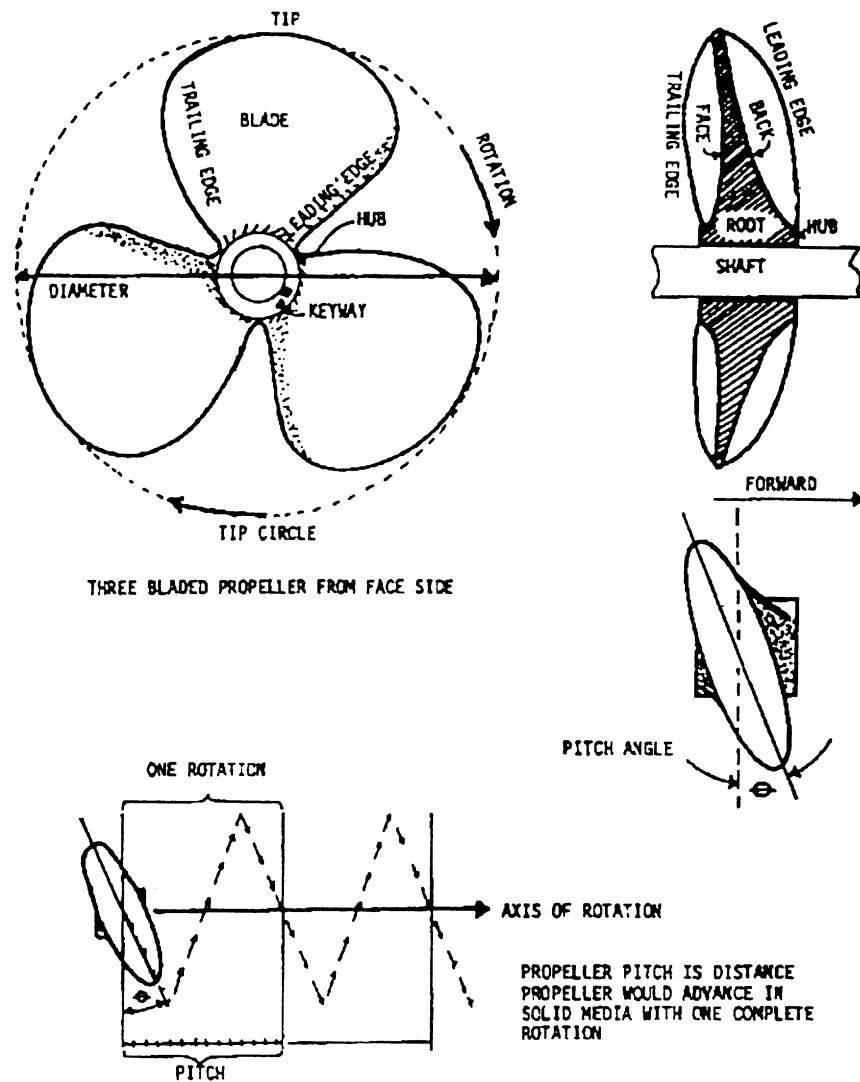
A propeller consists of blades and a hub. The area of the blade down at the hub is called the **root** and its outer edge is called the **tip** (see Figure 8-7).

B.12.b. Propeller edge

The edge of the blade that strikes the water first is the **leading edge**; the opposite is the **following edge**. The diameter of the screw, the circle made by its tips and its circumference, is called the **tip circle**. Each blade has a degree of twist from root to tip called **pitch** (see Figure 8-7).

B.12.c. Pitch

Pitch is the distance a propeller advances in one revolution with no slip (see Figure 8-7). Generally, less pitch in the same diameter propeller makes it easier for the engine to reach its preferred maximum RPM; thus, like putting a car in first gear, more power (and sometimes more speed) is available. Similarly, (like third gear in a car) more pitch may give more speed, but lower RPMs gives less power. Optimum performance is obtained when pitch is matched to the optimum design speed (RPM) of the engine.



Parts of a Propeller
Figure 8-7

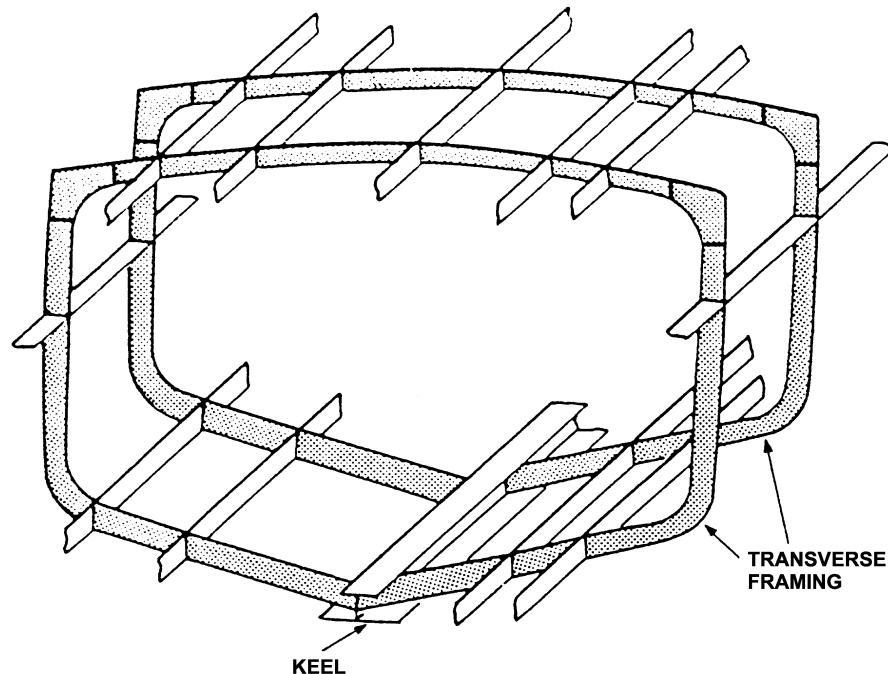
B.13. Frames

As previously stated, it is the framing that gives the hull its strength. Frames are of two types:



B.13.a. Transverse frames

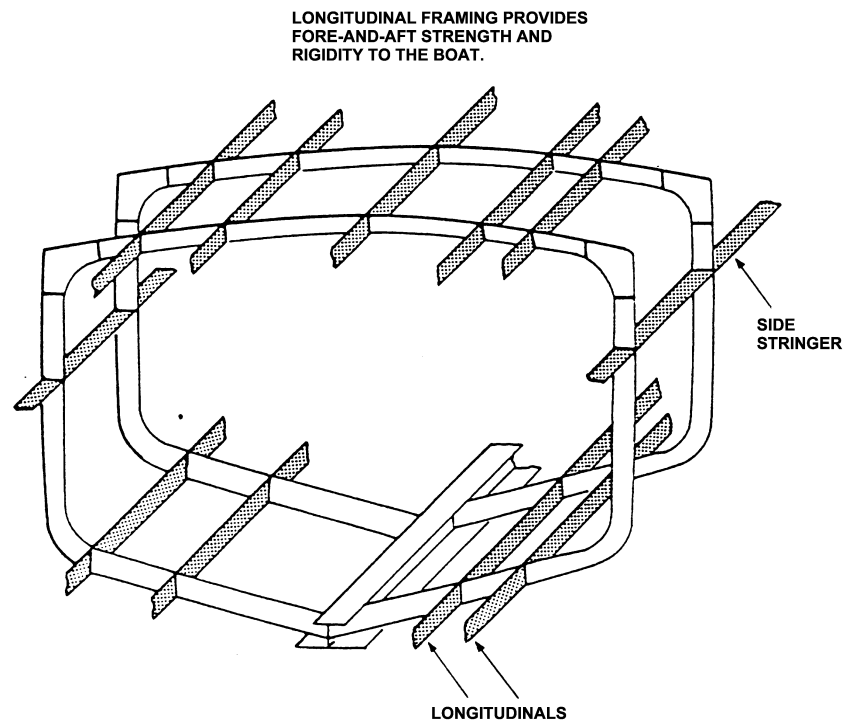
Watertight bulkheads or web frames are located at certain points in the hull to further increase the strength of the hull. Just as the keel is the backbone of the hull, transverse frames and are often referred to as ribs. Transverse frames extend athwartships and are perpendicular (vertical or upright) to the keel and are spaced at specified distances. (See Figure 8-8). They vary in size from the bow to the stern giving the boat hull its distinct shape when the skin is attached. They are numbered from the bow to the stern to help you quickly identify a particular location in the interior and, in the event of damage to the hull, to isolate the area of damage.



**Transverse Framing System
Figure 8-8**

B.13.b. Longitudinal frames

Longitudinal frames provide hull strength along the length of the hull (fore and aft). (See Figure 8-9). As you will note, they run parallel to the keel and at right angles to the transverse frames. In addition to strengthening the hull, the top longitudinal frames provide a skeletal structure over which deck plating is laid.



Longitudinal Framing System
Figure 8-9

B.14. Decks

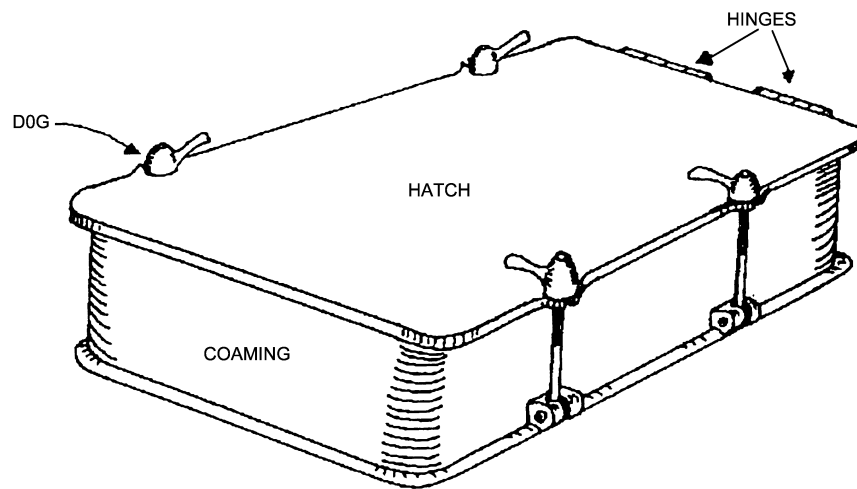
A deck is a seagoing floor and provides strength to the hull by reinforcing the transverse frames and deck beams. The top deck of a boat is called the weather deck because it is exposed to the elements and is watertight. In general, decks have a slight downward slope from the bow. The slope makes any water taken aboard run aft. A deck also has a rounded, athwartship curve called **camber**. The two low points of this curve are on the port and starboard sides of the boat where the weather deck meets the hull. Water that runs aft down the sheer line is forced to the port or starboard side of the boat by the camber. When the water reaches one of the sides, it flows overboard through holes, or **scuppers**, in the side railings.



Hatches and Doors

B.15. Hatches

If decks are seagoing floors, then hatches are seagoing doors. In order for a **bulkhead** (a seagoing wall) with a hatch in it to be watertight, the hatch must be watertight. A weather deck hatch is made watertight by sealing it into a raised framework called a **coaming**. Hatches operate with quick-acting devices such as wheels or handles or they may be secured with individual dogs (see Figure 8-10).



Water Tight Hatch
Figure 8-10

B.16. Scuttles

Scuttles are small openings. A "scuttle cover," fitted with a gasket and dogs, is used to secure the scuttle. A tool called a "T-handle wrench" is used to tighten down the scuttle cover dogs.

B.17. Doors

Watertight doors are designed to resist as much pressure as the bulkheads through which they provide access. Some doors have dogs that must be individually closed and opened; others, called "quick-acting watertight doors" have handwheels or a handle which operate all dogs at once.

**B.18. Gaskets**

Rubber gaskets form tight seals on most watertight closure devices. These gaskets, mounted on the covering surface of the closure device (e.g., door, hatch, scuttle cover), are pressed into a groove around the covering. The gaskets are sealed tight by pressing against a fixed position "knife edge."

B.19. Knife edges

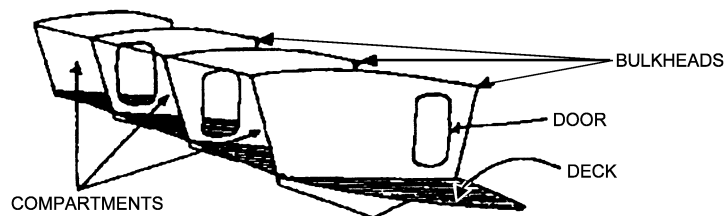
Watertight closures must have clean, bright, unpainted, smooth knife edges for the gaskets to press against. A well-fitted watertight closure device with new gaskets will still leak if knife-edges are not properly maintained.

CAUTION !

Scuttles must be secured for watertightness at all times except when they are open for inspection, cleaning, or painting. They must never be left open overnight or when crew members are not actually working.

B.20. Interior

The interior of a boat is compartmentalized into bulkheads, decks, and hatches. The hatches are actually "doors" through the bulkheads. With the hatches closed, the space between them becomes watertight and is called a **watertight compartment** (see Figure 8-11). These watertight compartments are extremely important. Without them the boat has no **watertight integrity** and a hole anywhere in the hull will cause it to sink. By dividing the hull into several watertight compartments, the watertight integrity of the boat is significantly increased. One or more of these compartments may flood without causing the boat to sink. A boat could be made unsinkable if its hull could be divided into enough watertight compartments. Unfortunately, excessive compartmentation would interfere with the engineering spaces and restrict your movement in the interior spaces.



Watertight Compartment
Figure 8-11



Boat Measurements

B.21. General

There are specific terms for the length and width of a boat and also specific methods for determining these measurements. The more common boat measurements are discussed below.

B.22. Overall length

The overall length of a boat is technically called the length overall (LOA) and is the distance from the foremost to the aftermost points on the boat's hull.

B.23. Waterline length

The waterline length of a boat is technically called the length on water line (LWL). It is the distance between fore and aft where the surface of the water touches the hull when a boat is normally loaded.

B.24. Beam and breadth

Beam and breadth are measures of a boat's width. **Beam** refers to the distance from the outside hull plating on one side of the boat to the outside hull plating on the other side. **Breadth** refers to the distance between the outside edge of a frame on one side of the boat to the outside edge of the same numbered frame on the opposite side.



Displacement

B.25. General	Displacement is the weight of a boat and is measured in long tons (2,240 lbs) or pounds.
B.26. Gross tons	The entire cubic capacity of a boat expressed in tons of 100 cubic feet.
B.25. Net tons	The carrying capacity of a boat expressed in tons of 100 cubic feet. It is calculated by measuring the cubic content of the cargo and passenger spaces.
B.27. Deadweight tons	Deadweight is the difference between the light displacement and the maximum loaded displacement of a boat and is expressed in long tons or pounds.
B.27.a. Light displacement	Light displacement is the weight of the boat excluding fuel, water, outfit, cargo, crew, and passengers.
B.27.b. Loaded displacement	Loaded displacement is the weight of the boat including fuel, water, outfit, cargo, crew, and passengers.



Chapter 8: Boat Characteristics



Section C. Watertight Integrity

Overview

Introduction

Watertight integrity describes a compartment or fitting that is designed to prevent the passage of water into it. An important concern in boat operations is to ensure the watertight integrity of the vessel. A boat may sustain heavy damage and remain afloat if watertight integrity is maintained. Doors, hatches, and scuttle covers must be securely dogged while the boat is underway and while it is moored and unattended by crew members.

In this section

These items are discussed in this section:

Topic	See Page
Closing and Opening Watertight Doors and Hatches	8-28
Entering a Closed Compartment After Damage	8-29



Closing and Opening Watertight Doors and Hatches

C.1. General

Watertight doors and hatches will retain their efficiency longer and require less maintenance if they are properly closed and opened as described below.

C.2. Closing

The procedure for closing a watertight door is as follows:

Step	Procedure
1	Begin by tightening a dog that is opposite the hinges.
2	Place just enough pressure on the dog to keep the door shut.
3	Tighten up the other dogs evenly to obtain uniform pressure all around the closing device.

For quick-acting watertight doors, simply turn the wheels or handles in the correct direction (clockwise).

C.3. Opening

If the dogs on watertight doors and hatches open individually, open the dog nearest the hinge first. This keeps the closing device from springing and makes loosening the other dogs easier.

For quick-acting watertight doors, turn the wheels or handles in the correct direction (counterclockwise).



Entering a Closed Compartment After Damage

C.4. General

NOTE

Suspect flooding if air escapes when you release the dogs on a door or hatch.

Do not open watertight doors, hatches, and scuttle covers on a damaged boat until you determine the following:

- flooding did not occur or, if flooded,
- further flooding will not occur if you open the closure.

CAUTION !

Extreme caution is always necessary when opening compartments below the waterline near hull damage.



Chapter 8: Boat Characteristics



Section D. General Boat Equipment

Overview

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- | | |
|--------------------------|---|
| D.1. Introduction | All boats should carry basic equipment for the routine procedures, such as tying up, or anchoring. There is also equipment that is needed to conduct specific operations, such as search and rescue, towing, or pollution response. Crew members must be familiar with the use of the equipment carried on board and where it is located. A complete listing of required equipment is contained in the Boat Outfit List . Each type of boat has its own outfit list. You will find outfit lists for all standard Coast Guard boats in their boat type manuals. For Coast Guard utility boats (UTBs) and motor lifeboats (MLBs), they are also in the <i>Motor Lifeboat (MLB) & Utility Boat (UTB) Standardization Program Manual</i> , COMDTINST M16114.24 (series). Each Auxiliary vessel should have a boat outfit of the types of items listed below. |
|--------------------------|---|
-
- | | |
|---|---|
| D.2. General boat equipment list | The general equipment found on Coast Guard boats and a brief statement of the purpose of each item is provided below. |
|---|---|
-



Item	Purpose
Anchors	For anchoring in calm, moderate, and heavy weather.
Anchor Lines	Provides scope to prevent the anchor from dragging. Enables retrieval of the anchor. Serves as an additional towline if necessary.
Chafing Chain	Assists in preventing chafing of the anchor line on the bottom.
Screw Pin Shackle	Attaches chafing chain to shank of anchor.
Swivel	Allows anchor line to spin freely.
Thimble	Prevents chafing of anchor line at connection point with associated hardware
Towline	Used for towing astern
Alongside Lines	Used for alongside towing, joining to kicker hooks, passing a pump, etc.
Heaving Lines (75' to 100')	Used for passing a towline when a close approach is not possible
Grapnel Hook with 100' of line	Used for recovering objects from the water.
Wood Boat Hook	For reaching dockside lines, fending boat from boat, and recovering objects from water.
Kicker Hook	Attaches to trailer eyebolt on small boats for towing, weighing anchor, or disabled boats, etc.
Shackles	For weighing a disabled boat's anchor, attaching towing bridles to towlines, attaching towlines to trailer eyebolt, etc.
Lead Line (Sounding Pole)	Used in determining water depth and bottom type.
First Aid Kit	For emergency treatment of injuries suffered by crew members or survivors.
Personnel Survival Kits	Used by crew members in the event of a capsizing or person overboard.
Heavy Weather Crew Safety Belt	For personnel safety during heavy weather or surf operations. Secures a crew member to the boat.



Item	Purpose
PFDs, each with a distress signal light, a whistle, and retroreflective tape	Provides personal flotation support. Keeps the head of an unconscious or injured person out of the water. Worn by crew members and given to survivors who are brought on board. Also worn by survivors who remain on their own boat when it is in tow.
Ring Buoy, 30" diameter	Used during person overboard emergencies.



Chapter 8: Boat Characteristics



Section E. Troubleshooting Basic Mechanical Problems

Overview

Introduction

Troubleshooting mechanical problems is typically the responsibility of the boat engineer, if one is assigned. However, not all Coast Guard boats or Auxiliary facilities deploy with a dedicated boat engineer. Boats without engineers should be able to provide basic help for themselves and those vessels that they are trying to assist. Often, a simple mechanical fix can avoid a long tow or other loss of use of a Coast Guard boat. The primary source for a boat's maintenance and repair requirements should be the operator manuals that come with the boat.

NOTE

In all casualties keep the station/unit command advised of the problem and updates of changing status. If in restricted water, consider anchoring.

In this section

These items are discussed in this section:

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Troubleshooting Diesel Engines

E.1. General

Diesel engines are very common as inboard engines for boats. They are very reliable when properly maintained. Typical problems, their possible causes, and potential solutions are outlined below.

Problem	Cause	Solution
1. Engine will not turn over when starter button is pushed.	Main power switch off.	Turn main power switch on.
	Battery cable loose or corroded.	Tighten, clean, or replace cable, terminals.
	Starter motor cable loose or corroded.	Tighten, clean, or replace cable.
	Batteries are low or dead.	Charge or replace batteries.
	Engine seized hydraulic lock (fuel or water in cylinders).	Remove injectors, bar engine over by hand after (to relieve pressure & prevent internal damage).
	Misalignment of controls, neutral safety switch.	Make appropriate adjustment, realign controls.
	Non-operation or chattering solenoid switch.	Replace, repair cable. Replace solenoid. Check battery voltage.
2. Irregular engine operation. (Engine runs unevenly or stalls.)	Strainers & fuel filter clogged.	Clean, replace, or purge air (bleed).
	Lines & fitting leaking.	Check fuel lines & fittings for leaks, tighten, or replace.
	Insufficient fuel/aeration of fuel.	Sound tanks-shift suction, refuel if necessary.
	Binding fuel control linkages.	Inspect and adjust.



	Insufficient intake of air.	Inspect intake for obstructions from air silencer. Check emergency air shutdown for possible restriction.
3. Engine overspeeds or overruns.	<p>Loose or jammed linkage.</p> <p>If engine RPMs increase, an internal engine malfunction has occurred. A stuck injector, a clutch that slipped into neutral, a lost prop, a ruptured lube oil seal could be the cause. Most engines overspeed after someone has performed maintenance. For this reason, it is most important that the operator assess what is occurring promptly. Regardless, when the engine overspeeds follow the procedure in the next column.</p>	<p>Tighten or free linkage.</p> <p>If an engine appears to be operating normally at cruising speed but fails to slow down as the throttle is being returned to neutral, do not place the throttle in neutral until a determination is made that the engine is in fact out of control (i.e., check for throttle linkage that became detached. By keeping the engine in gear it will prevent it from being destroyed. Secure the engine by following the steps below:</p> <p>If overspeed continues pull engine stops, (kill switch). If engine RPMs still overspeed, shut off fuel supply. If problem continues stuff rags against air silencer. As a last resort, shoot CO₂ into the air intake.</p>
4. Engine oil pressure high.	<p>Incorrect grade of oil.</p> <p>Oil filters dirty.</p> <p>Cold engine not up to operating temperature.</p> <p>Relief valve stuck.</p>	<p>Monitor and if pressure becomes too high, secure engine.</p> <p>Change oil filters.</p> <p>Warm up engine.</p> <p>Adjust, remove, or clean.</p>



	<p>External oil leaks.</p> <p>Internal oil leaks.</p> <p>Worn or damaged engine parts.</p>	<p>Tighten connections if possible. Add oil monitor and secure engine if necessary.</p> <p>Secure engine.</p> <p>Monitor, add oil, and secure engine if excessive consumption continues.</p>
5. Engine surges.	<p>Air in fuel system.</p> <p>Clogged fuel strainers/filters.</p> <p>Aeration of fuel (from heavy weather).</p> <p>Governor instability.</p> <p>Loose throttle linkage.</p>	<p>Secure engine. Bleed air out of fuel system.</p> <p>Switch/change fuel filters.</p> <p>Shift to lower fuel function.</p> <p>Adjust the buffer screw (G.M.) Check free movement of fly weights.</p> <p>Tighten linkage.</p>
6. Marine (reduction) gear fails to engage.	<p>Loss of gear oil.</p> <p>Strainer/filter clogged.</p> <p>Loose, broken maladjusted linkage.</p>	<p>Add gear oil. Check and correct leaks.</p> <p>Clean strainer, change filter.</p> <p>Inspect and correct, as necessary.</p>
7. Unusual noise in reduction gear.	<p>Loss of gear oil.</p> <p>Worn out reduction gear.</p> <p>Misalignment of gear.</p>	<p>Secure engine, check gear oil. Refill and resume operation for trail.</p> <p>Secure engine.</p> <p>Secure engine.</p>
8. Loss of gear oil pressure to reduction gear.	<p>Loss of gear oil.</p>	<p>Inspect all high pressure lines for leaks and repair. If unable to repair, secure engine.</p>



9. Temperature of engine coolant higher than normal.	Thermostat faulty, expansion tank cap faulty, leaky hoses, etc.	Inspect all lines for leaks and repair.
10. Engine smokes a. Black or gray smoke	<p>Incompletely burned fuel.</p> <p>Excessive fuel or irregular fuel distribution.</p> <p>Improper grade of fuel.</p>	<p>High exhaust back pressure or a restricted air inlet causes insufficient air for combustion and will result in incompletely burned fuel. High exhaust back pressure is caused by faulty exhaust piping or muffler obstruction and is measured at the exhaust manifold outlet with a manometer, a meter gauge which measures differential pressure.</p> <p>Replace faulty parts. Restricted air inlet to the engine cylinders is caused by clogged cylinder liner ports, air cleaner or blower air inlet screen. Clean these items. Check the emergency stop to make sure that it is completely open and readjust if necessary.</p> <p>Check for improperly timed injectors and improperly positioned injector rack control levers. Time the fuel injectors and perform the appropriate governor tune up.</p> <p>Replace faulty injectors if this condition continues. Avoid lugging the engine as this will cause incomplete combustion.</p> <p>Check for use of an improper grade of fuel.</p>



b. Blue smoke.	Lubricating oil being burned (blow by valves/seals).	Check for internal lubricating oil leaks. Conduct compression test. Check valve and rings. Return to mooring.
c. White smoke.	Bad oil seals in the turbocharger. Misfiring cylinders. Cold engine. Water in the fuel.	Check for faulty injectors and replace as necessary. Allow engine to warm under a light load. Drain off strainers/filters. Strip fuel tanks.



Troubleshooting Gasoline Inboard Engines

E.2. Indicators

Normal operation indicators are:

- a. Ease of starting.
 - b. Engine reaches specified RPMs at full throttle.
 - c. Correct shift and reverse RPMs.
 - d. Smooth idle.
 - e. Correct operating temperatures.
 - f. Adequate cooling water discharge and kill switch.
 - g. Smooth acceleration from idle to full RPMs.
-

E.3. Basic trouble shooting

An initial quick check of the following may reveal a simple fix for a problem that does not appear simple at first:

- a. A visual inspection for obvious damage.
 - b. A rough compression check can be accomplished by removing a spark plug and placing a finger over the opening and cranking the engine.
 - c. Check the spark plugs for fouling.
 - d. Check ignition system for spark.
 - e. Check linkages for adjustments.
 - f. Check neutral/start switch.
 - g. Check gear case and lubricants in the engine.
-

E.4. Repairs advice

The manufacturer's technical manual should be consulted for all adjustments and specifications. Use the following examples as a guide but always follow the specific engine's technical manual.



Problem	Check
1. Engine stops suddenly after a period of operation.	Inspect for obvious damage of engine components such as loose wires, leaking fuel lines, leaking of coolant, excessive heat. Check ignition system for broken or loose wiring, distributor cap, points, or coil. Check for clogged fuel filters, quality/quantity of fuel.
2. Engine stops suddenly with no spark to spark plugs.	Inspect for obvious damage, check the ignition system for broken or loose wiring, distributor cap, points, or coil.
3. Engine stops, restarts when cool and stops again when hot.	Have the ignition coil and condenser checked out; they may be breaking down when hot.
4. Engine stops after a period of rough uneven operation.	Inspect for obvious damage. Check the ignition system for broken or loose wiring, distributor cap, points, or coil. Check the battery, ignition timing, and the fuel filter.
5. Engine runs by spurts, and stops with the fuel filter clean.	Check the fuel tank and fuel lines. Check the ignition system for obvious damage. Check ignition timing and points. Check the fuel pump for proper operation.
6. Engine runs by spurts, stops and water is present in the fuel filter.	Clean fuel filter. Check the fuel tank for presence of water and drain if necessary. If the carburetor is filled with water. It must also be drained. Take appropriate action safety precautions to avoid fire explosion.

WARNING 

Beware of fuel vapors before starting engine.

7. Engine misses, gallops, spits, backfires and has a loss of power.	Inspect for obvious damage. Carburetor may be dirty. Check ignition system for broken or loose wiring, distributor cap, rotor points and coil. Check fuel filter and fuel lines. Check for plugged vent.
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8. Engine starts hard, especially in cold weather.	Battery voltage may be low. Check ignition timing and points. Check ignition system for obvious damage. Exhaust valves may be burned. May have to change to a lighter engine oil.
9. Engine pops and pings in exhaust pipe at all speeds.	Exhaust valves may be burned, worn piston rings or worn valve guides. Time for engine overhaul. Timing may be off. Too low octane fuel.
10. Starter turns engine but engine will not start.	Check fuel level. Inspect for obvious damage to ignition system, broken or loose wiring, distributor cap, rotor points, or coil. Check ignition timing and points. Check fuel pump.



Casualties Common to Both Diesel and Gasoline Engines

E.5. General

Diesel and gasoline engines, though both run on a type of petroleum, operate in different ways. However, there are common problems, causes, and solutions that apply to both.

Problem	Cause	Solution
1. Starter whines. Engine doesn't crank over, doesn't engage Starter relay may chatter.	Defective starter. Bendix is not engaged. Defective starter relay.	Call for assistance. Replace or repair starter or relay. Check bendix on return to dock.
	Low battery voltage.	Check battery cables for loose connection (or corrosion) to starter. Charge or replace battery.
2. Engine fails to start with starter turning over.	Fuel stop closed.	Open it.
	Fuel shutoff valve closed.	Open it.
	Clogged air cleaner.	Remove and clean air cleaner.
	Fuel supply exhausted.	Refill fuel tanks, bleed and prime system.
	Clogged strainer.	Shift strainer and clean, bleed off.
	Fuel filters clogged.	Shift and replace elements, bleed air off.
	Clogged/crimped restricted fuel line.	Replace or repair fuel line.
	Inoperable fuel pump.	Replace.
	Emergency air shut off blower tripped.	Reset.
	Clogged air intake.	Remove, clean, or replace.



	Low battery voltage causes slow cranking.	Charge battery or replace.
	Cold engine.	Check hot start.
3. Engine temperature high.	Closed or partially closed sea suction valve.	Check raw water overboard discharge; if little or none, check sea suction valve. Open it.

NOTE 

For all high temperature situations the immediate action is to place the throttle in neutral then look for the probable cause.

When an overheated engine must be secured, turn the engine over periodically to keep it from seizing.

	Dirty plugged raw water strainer. (Especially in shallow water.)	Replace strainer.
	Broken raw water hose.	Secure engine, replace hose.
	Broken or loose raw water pump drive belt.	Secure engine, replace or tighten belt.
	Faulty raw water pump.	Call for assistance.
	Clogged heat exchanger.	Inspect heat exchanger.
	No/low water in expansion tank (fresh water system).	Handle the same as for a car radiator-open with caution releasing pressure before removing cap. With engine running add fresh water.
	Broken fresh water hose.	Secure engine, replace, add fresh water.
	Broken belts/drive fresh water system.	Treat same as raw water system.



	<p>Faulty water pump, fresh water system.</p> <p>Thermostat stuck, fresh water system.</p> <p>Water in lube oil.</p> <p>Blown head gasket.</p> <p>Engine overload (towing too big a vessel or towing too fast.)</p> <p>Ice clogged sea strainers (especially during operation in slush ice.)</p> <p>Air bound sea chest.</p> <p>Rubber impeller on raw water pump is inoperable.</p>	<p>Call for assistance.</p> <p>Secure engine, remove thermostat, add fresh water.</p> <p>Check lube oil for “milky” color. If found, secure engine.</p> <p>Secure engine, lock shaft, return to mooring.</p> <p>Reduce engine speed.</p> <p>Shift sea strainer, open deicing valve.</p> <p>Open/clear sea chest vent valve.</p> <p>Renew.</p>
4. Engine lube oil pressure fails.	<p>Lube oil level low.</p> <p>External oil leak.</p> <p>Lube oil dilution.</p> <p>Lube oil gauge defective.</p>	<p>If above red line, check oil, add if needed. If below red line, secure engine.</p> <p>Tighten fittings if possible. If not, secure engine.</p> <p>Secure engine if beyond 5% fuel dilution.</p> <p>Take load off engine, if applicable, check to confirm if gauge appears to operate normally.</p>



	Mechanical damage to engine.	Secure engine.
5. No oil pressure.	Lube oil pump failure. Defective gauge.	Secure engine. Repeat all procedures for item #4 above. Verify that failure is only in gauge. Otherwise secure engine.
6. Loss of electrical power.	Short circuit/loose connections causing tripped circuit breaker or blown fuse. Corroded wiring connections Overloaded circuit. Dead battery	Check for shorts/grounds. Reset circuit breakers, replace fuses as necessary. Clean or replace cables/wires. Secure all unnecessary circuits, reset circuit breakers, replace fuses. Charge or replace battery.
7. Alternator indicator light on.	Loose/broken belt. Loose terminal connections. Defective alternator or regulator.	Replace/tighten belt. Inspect and tighten as necessary. Replace defective item.
	REGARDLESS OF CAUSE, FOLLOW PROCEDURES BELOW.	
	Packing too tight. Bent shaft. Valve to stern closed/restriction in the line.	Reduce speed, but do not secure engine or shaft. Reduce speed, check hull for damage or leaks. Loosen packing nuts by turning the two nuts securing spacer plate. When the housing is cool, tighten the two nuts on the space plate until a discharge of about 10 drops of water per minute is obtained.



		<p>In cases where nuts will not back, use raw water from a bucket, wet rag and place on shaft packing housing.</p> <p>Maintain watch on water flow (step #3) and adjust discharge as needed.</p> <p>Check coolness by placing the back of your hand on the packing gland housing.</p>
8. Shaft vibration.	REGARDLESS OF CAUSE FOLLOW THE PROCEDURE BELOW.	
	Damaged or fouled propeller.	Place throttles in neutral if possible.
	Bent shaft.	Reduce speed, check hull for damage or leaks.
	Cutlass bearing worn.	Check for line fouled in the propeller or shaft.
	Engine or shaft out of alignment.	<p>Slowly increase speed on engine. On twin propeller boats, do one engine at a time to figure out which shaft is vibrating.</p> <p>If vibration continues even at low speeds, secure the engine or engines involved.</p> <p>If engines are secured, lock the shafts.</p>
9. Engine room fire. a. Petroleum based.	FOR ALL FIRES FOLLOW THE PROCEDURE BELOW.	
	Oil and grease in bilges.	Secure engines, turn off fuel at the tank if possible.
	Fuel or lube oil spill.	Call for assistance at earliest opportunity.
	Improper containers of flammable liquids.	Secure electrical power to and from engine room.
	Improper venting of engine room before starting engine.	Use any available portable fire extinguisher (Purple K, CO ₂ , etc.)



b. Electrical fires.	Seal compartment. Turn off electricity if possible. Select the proper extinguished agent and employ.
10. Engine stops suddenly and will not turn through a full revolution.	Check for an obstruction within the cylinder such as water or a broken, bent or shut valve.
11. Engine stops firing hot and won't turn over when cool.	The engine seized for one reason or another and must be overhauled.
12. Engine stops with a loud clatter.	Inspect for obvious damage. Damage may be to internal parts such as valve, valve spring, bearings, piston rings, etc. Overhaul of the engine is required.
13. Engine oil level rises, oil looks and feels gummy.	There may be coolant leaking into the engine oil. Check for internal leakage. Repair the engine before continuing operation.
14. Engine oil rises or feels thin.	Fuel is leaking into the crankcase. Check fuel pump. After problem has been corrected change oil and filters.
15. Hot water in bilges.	Inspect the exhaust piping muffler, and/or cooling water level. It is probably leaking into the bilges. Check all hoses.
16. Engine runs with a thumping or knocking noise.	Inspect for obvious damage to internal parts of the engine. They may be damaged. Disassemble the engine and repair or overhaul.



Troubleshooting the Outboard

E.6. General

Outboard motors are very common on recreational boats and many Coast Guard boats. The operator manual provides the best guidance. Working over the transom of the boat poses a hazard to the operator and for loss of parts and tools.

Problem	Possible Cause/Correction
1. Engine won't start.	<ul style="list-style-type: none">• Fuel tank empty.• Fuel tank vent closed.• Fuel line improperly connected or damaged; check both ends.• Engine not primed.• Engine flooded, look for fuel overflow.• Clogged fuel filter or line.• Spark plug wires reversed.• Loose battery connections.• Cracked or fouled spark plug.• Fuel pump not primed.
2. Starter motor won't work (electric starter).	<ul style="list-style-type: none">• Gear shift not in neutral.• Defective starter switch (sometimes gets wet and corrodes if motor is mounted too low).
3. Loss of power.	<ul style="list-style-type: none">• Too much oil in fuel mix.• Fuel/air mix too lean (backfires).• Fuel hose kinked.• Slight blockage in fuel line or fuel filter.• Weeds or some other matter on propeller.• Water has condensed in fuel.• Spark plug fouled.• Magneto or distributor points fouled.



4. Engine misfires.	<ul style="list-style-type: none"> • Spark plug damaged. • Spark plug loose. • Faulty coil or condenser. • Spark plug incorrect. • Spark plug dirty. • Choke needs adjusting. • Improper oil and fuel mixture. • Dirty carburetor filter. • Partially clogged water intake. • Distributor cap cracked.
5. Overheating.	<ul style="list-style-type: none"> • Mud or grease on cooling system intakes. • Too little oil. • Water pump's worn or impeller (rubber) is broken or sips. • Defective water pump.
6. Blue smoke.	<ul style="list-style-type: none"> • Spark plugs are fouled, means too much oil.
7. Engine surges.	<ul style="list-style-type: none"> • Out board not properly mounted-propeller rides out of the water. • Carburetor needs adjustments.
8. Poor performance on boat.	<ul style="list-style-type: none"> • Wrong propeller. • Engine improperly tilted compared with transom. Engine should be vertical when boat is underway. • Bent propeller-usually accompanied by high level of vibration. • Improper load distribution in boat. • Heavy marine growth on boat bottom. • Cavitation.



Steering Casualty

E.7. General

A steering casualty may have a simple solution or require outside assistance. It may also test your boat handling skills if the boat has two propellers. General advice is provided below.

Problem	Possible Cause/Correction
1. Broken or jammed cable.	<ul style="list-style-type: none">• Rig emergency steering as applicable. Advise operational commander.
2. Broken hydraulic line, or hydraulic systems malfunction.	<ul style="list-style-type: none">• Inspect hoses for leaks, check fluid level, add if necessary.• Replace hose if spare is on board.• Rig emergency steering as applicable.• Notify controlling unit.• Steer with engines if twin propeller.• Try to center rudder amidships.• Anchor, if necessary.
3. “Frozen”, damaged or blocked rudder, outdrive or outboard	<ul style="list-style-type: none">• Attempt to free, if possible.• Center rudder, if possible, and block in place.



Basic Engine Maintenance for Auxiliary Facilities

E.8. Maintenance logs

A very important maintenance procedure is to maintain a hull and engine maintenance log. Ideally, the log should be in two parts. One part would include a series of alphabetically arranged entries: battery, filters, oil, zincs, etc. (This makes it easy, for example, to look up “S” for spark plugs or “P” for points.) The other should contain several pages available for chronologically entering haul-outs and major maintenance work. To structure the log properly, the engine manufacturer’s maintenance manual is needed. Also, a good practice is to buy a large ring binder and put in it every instruction or technical manual for electronics, instruments, heads, stoves, etc. that comes with the boat.

E.9. Basic maintenance actions

There is not enough space in this chapter to write a maintenance manual for each type of Auxiliary boat. The primary source for a boat’s maintenance requirements should be the engine maintenance manual that came with the boat. However, any Auxiliarist can accomplish the following engine maintenance actions:

- a. Change engine oil, oil filters, and fuel filters.
- b. Select, gap, and properly torque to specifications, new spark plugs.
- c. Check and change, if necessary, heat exchanger zincs (if equipped). In some areas this should be done monthly.
- d. Drain and replace hydraulic drive fluids.
- e. Replace and adjust engine fan belts.
- f. Adjust and tighten stuffing box fittings, steering cable or hydraulics, stuffing boxes, and hull fittings.
- g. Replace defective engine hoses.
- h. Clean the air cleaner and flame arrester.
- i. Check and charge batteries.
- j. Lube and maintain salt-water intakes/sea cocks.

NOTE

Keep the tools aboard needed to affect these repairs. With the right spares aboard and the hand tools to install them, there is no need to become a SAR case.

E.10. Advanced maintenance actions

The more experienced power boater can change ignition points, adjust timing, align engine coupling faces, etc.



E.11. Inboard boats kept in salt water

A selection of wire brushes, spray cans of primer, engine touch up paint, and a small 5x7 mirror should be kept on board. About twice a month, get in the bilges and really inspect the engines (mounts, etc.,) for rust and corrosion. When found, wire-brush it off and spray with touch up paint. (There is no reason for engines to be lumps of rust.) Also, while minutely going over the engine, look for leaking hoses, gaskets, loose wires, etc. Many engine problems relate to electrical problems, including loss of electrical ground and oxidation of leads or connectors. Inspect these areas regularly. The 5x7 mirror is for inspecting the blind side of the engine. Eliminate many occasions to be towed by following meticulous maintenance procedures.

E.12. Buying engine parts

A note about buying engine parts. Spark plugs, hoses, belts, ignition wires, and points can be purchased at auto supply stores. However, alternators, distributors, and carburetors used on boats must have certain marine safety features, screens, etc. Any attempt to replace them with auto components runs the risk of fire and explosion.

NOTE 

Do not use auto parts on your boat.